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STEM for English Learners

Math and science are the engines of innovation. With these engines we can lead the world. We must demystify math and science so that all students feel the joy that follows understanding. - Dr. Michael Brown, Nobel Laureate for Medicine

Science, technology, engineering, and math typically have been taught as separate, independent domains. More recently, STEM education has focused on: (1) a more unified curriculum or "meta-discipline" of STEM, one in which technology and engineering are used within science and math and STEM is integrated throughout the curriculum and (2) transforming the teacher-centered classroom to a more problem-solving, discovery-based, exploratory curriculum. Within this context, math is a "gatekeeper" to a college education and to advanced STEM education. However, research shows that EL students tend to take fewer, and lower-level, math courses than English-proficient students (c.f., Wilde).

We offer herein a range of articles on STEM education for ELs; a unifying theme is the importance of moving students toward independent learning and the ability to demonstrate a deeper understanding of STEM content areas, improved language, and increased literacy skills. The majority of these articles specifically address language issues—building vocabulary in science (August, et al.; Crowther, et al.), technology (Pritchard & O'Hara), and math (Bolt & Herrera); understanding writing concepts in science (Berg; Nagle & MacDonald); and developing advanced literacy skills in science (Anstrom & DiCerbo; Breitberg, et al.). Additional articles suggest professional development activities that provide teachers with increased knowledge in how to improve student skills in science (Leier & Fregeau) and math (Bright; Gerena & Keiler), while another provides various web-based resources for educators of EL students (Sonnenberg). Other articles focus on innovative approaches to developing reasoning skills in engineering (Carr, et al.), in math (Aguirre-Muñoz), and last, but certainly not least, the use of native language to enhance literacy in science education is supported (Bravo).

Advanced Literacy in Science: Language Demands and PD Practices

Kris Anstrom and Pat DiCerbo

If students are to be ready to pursue post-secondary education coursework and careers in STEM, they must be able to read and write in these disciplines well above the levels currently demanded of them by U.S. schools [1]. As students move from secondary classrooms to post-secondary environments, they will be expected to learn an increasing amount of STEM content independently through the process of reading and writing texts. Thus, preparing students for post-secondary learning in STEM must include helping them acquire the advanced literacy skills necessary to comprehend and write increasingly complex academic texts.

Mastering advanced literacy is demanding for all students, but is especially daunting for those students who struggle with linguistic challenges, such as ELs, students who speak non-standard dialects of English, and students who have not been exposed sufficiently to the language and literacy demands of different content areas. It is necessary for teachers to lay the foundations for these students' advanced literacy by teaching how discipline-specific "information is organized, connected, and categorized" [2, p.199]. This article describes the literacy demands of one STEM field, science, reviews the teacher knowledge and skills associated with advanced literacy instruction in science at the secondary level, and offers promising approaches to PD for science teachers who work with ELs.

Language and Literacy Demands in Science Education

Science is a specialized discipline with specialized ways of making meaning. The scientific meanings conveyed in secondary classroom texts, assignments, and assessments represent the values and ways of thinking of scientific communities. Science texts, for example, are set apart by such features as extensive use of passive voice, a grammatical device used to express objectivity. Science texts also rely on condensed complex messages that convey a great deal of information in each sentence. The register of science shows variation in vocabulary, grammar, and discourse patterns (Table 1).

The application of what is known as functional linguistics to classroom texts has helped clarify the distinctive patterns and complexity associated with classroom science texts. Studies in this tradition have identified and described four genres of science texts: procedure, procedural recount, science report, and science explanation. The first two, procedures and procedural recounts, are associated closely with concrete experience, and so tend to be easier to describe and understand. As students progress into reading and writing more advanced genres such as reports, scientific knowledge is presented in more general and abstract ways (e.g., *Solutions are mixtures that combine two or more substances*). Differences in these genres also are reflected in grammar and word choice. In science explanations, features such as clauses and embedding allow for "the logical organization and sequencing of knowledge in ways that enable the accumulation of information" [3, p. 116]. Secondary science texts tend to pack more information into fewer words and clauses than in spoken English or in simplified/level texts. As the genres increase in complexity, students face greater challenges in comprehending and producing them. To access these densely-written, highly abstract texts, students must learn the new lexical and grammatical

Editor's Notes

The following signs and abbreviations are used in this issue.

— *Success stories* describe promising projects or ideas

— *Teachers' gems of wisdom* share effective instructional practices

— *Information pieces*

EL— English learners
ELP—English-language proficiency
ESEA—Elementary and Secondary Education Act
ESL—English as a Second Language
ESOL—English for Speakers of Other Languages
PD—Professional development
SLA—Second Language Acquisition
STEM—Science, Technology, Engineering, and Mathematics
USDE—U.S. Department of Education

Citations in the text are in [bracketed numbers]; the references follow each article in the same numerical order. Other notes are indicated by consecutively numbered superscripts.

Table 1. Vocabulary, Grammar, and Discourse/Organization

Level	Academic Language Feature	Definition and Examples Typical of Expository Texts in Science
Lexical/ Vocabulary Level	General Academic Vocabulary	*Concept, Process*
	Science-specific Vocabulary	*Evolution, Natural Selection*
Grammatical/ Syntactic Level	Grammar	*The concept of fitness, Darwin argued, was central to the process of evolution by natural selection. (Embedding)*
Discourse/ Organizational Level	Academic Language Functions	*Explain how natural selection affects the evolution of a species, according to Darwin's theory of evolution.*

forms and patterns. For many students this learning does not occur without "carefully scaffolded experiences with written texts and explicit teaching of knowledge about language" [4, p. 514].

Science Teacher Knowledge, Skills, and Practice

To meet the advanced literacy needs of ELs, teachers need to have sufficient linguistic knowledge and skill to make the language expectations for academic assignments clear, and to teach students how choices in word, grammar, and purpose lead to differences in how ideas are portrayed in texts. Within the science education reform community, however, a primary focus has been on science inquiry activities to raise interest in science and foster scientific habits of mind. What has been missing is instruction in the literacy skills needed to access science content through texts. Reading science texts should be an essential component of science instruction. Yet the typical high school science teacher may not be prepared to deconstruct the complexity of science words, language structures, and discourse patterns that are critical for understanding core science concepts, participating in science-related discussions, and excelling on science tasks and assessments. Moreover, high school teachers typically plan for and deliver content instruction without the benefit of collaboration with their EL and reading specialist colleagues that could enhance advanced language and literacy support.

PD for Advanced Literacy in Science

PD research indicates that learning is a cyclical rather than a linear process that provides teachers with the opportunity to "revisit partially understood ideas as they try them out in their everyday context" [5, p. 15]. Science PD can use this cyclical design to help science teachers develop knowledge of the specialized language of their discipline and apply that knowledge to their instruction.

One such PD intervention used with high school language arts teachers was designed to support EL writing by providing teachers with a deeper knowledge of the linguistic features of written texts and of ways to address EL writing errors. Using a functional linguistics approach, the professional development began by building teachers' knowledge of the patterns and structures of complex texts and the ways in which these helped create discipline-specific meaning. The instruction also focused teachers on analyzing student writing in ways that more "directly foster the development of students' academic language development" [6, p.4]. Findings from this study showed improvements in teacher understanding of academic language and in the level of specificity of the feedback teachers were able to provide on student writing.

A second PD intervention, also premised on functional linguistics, engaged history teachers in a meaning-based approach to deconstructing sentences in history texts [7]. Teachers identified text passages that contained key concepts students were required to learn, and learned to unpack the text by moving through it clause by clause. As a result, teachers gained greater knowledge of the language patterns used to write history texts, and could plan lessons that engaged students in analyzing these language patterns. Study results showed that this approach facilitated EL and English-proficient students' advanced literacy skills and gave them a deeper understanding of history content.

A third type of intervention piloted for secondary teachers of science and mathematics also is based on the functional analysis of language [8]. The intervention was designed to support teachers in acquiring a deeper understanding of the language and literacy demands of their content areas by collaborating with English-language teachers to develop standards-based academic language resources for ELs. Through the analysis of standards-based materials, teams of educators developed their awareness of the discipline-specific language and literacy demands of their content areas. Participants identified the academic vocabulary, grammatical structures, and language functions associated with standards-based materials, and developed and used academic language frameworks to then modify curriculum and PD.

Conclusion

There is a growing awareness in the PD literature of the critical role that advanced literacy plays in students acquiring science knowledge, particularly as they transition from more teacher-supported learning experiences to the independent learning required in college and career. The three interventions described here build on this idea and demonstrate that a deep understanding of science is related to the ability to understand and use academic texts. PD interventions designed to engage teachers in analyzing the language patterns and structures of standards-based materials and texts and then applying this knowledge to their teaching show promise for improving ELs' advanced language and literacy skills.

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Using Functional Language Analysis to Develop Scientific Thinking

James Nagle and Rita MacDonald

To prepare a greater number of our high school students for the rigors of a career in science, our high schools need to tap the potential of all students, including ELs. Education researchers and teachers who work with ELs have long known that sheltered content instruction alone is insufficient to close the achievement gap between ELs and English-speaking peers, especially in academically rich, content-specific courses like biology [1; 2]. As students move through school, the language of each content area becomes more and more sophisticated and technical. Unfortunately, most high school teachers do not have the training and experience to provide explicit language instruction in their content area [3; 4]. This is especially the case for science teachers. To reduce the achievement gap in content-specific courses like biology, high school science teachers need to undergo a paradigm shift toward teaching the language of science as part of their instruction.

At South Burlington High School in Vermont, two teachers, with the assistance of two faculty members at Saint Michael's College, have created a co-teaching model that integrates science content with the academic language of science. The program involves matching an ESL teacher with a biology teacher. These two teachers, who form the center of the collaboration, plan, teach, and assess student work in a biology course that includes ELs. The purpose of this article is to discuss briefly the elements of this collaboration and how it integrates the academic language of science with the content of biology.

Systemic Functional Linguistics

The theoretical foundation of our collaboration involves the use of functional language analysis to identify meaning in science texts and course materials, and to develop corresponding teaching strategies for scaffolding students' construction of meaning in biology [5; 6]. "The language of science is simultaneously technical, abstract, dense and tightly knit ... this language plays a central role in the construction and representation of scientific knowledge, processes, and worldview" [5, p. 20]. To construct meaning from scientific texts and then to express their own reasoning in scientific contexts, students must master this technical, abstract, and dense scientific language. Using functional language analysis, our team of teachers developed strategies for students, especially ELs, for using the language of science to understand the content of biology and to express their thinking using scientific language.

Teaching Students to Decode Academic Text

The teachers started small by selecting an instructional unit on cells and asking the students to read a chapter from the biology text. Teachers then facilitated a series of class and small group discussions investigating the language of the text—at the level of vocabulary, at the level of abstraction, and at the level of scientific thinking. At the level of vocabulary, teachers helped students learn technical words unique to biology (e.g., *osmosis*) and everyday words with technical meaning in biology (e.g., *passive transport*). Teachers then pointed out how the text used certain nouns as abstractions to define processes (e.g., *diffusion*) or qualities (*frequency*), and that these abstract nouns derive from verbs (*diffuse*) or adjectives (*frequent*) that students already know.

Using the text, teachers taught students a recurring pattern in scientific writing by illustrating how the use of these nominalizations recast qualities and processes (adjectives and verbs) as nouns that could be used as subjects of additional reflection and discussion in subsequent sentences, thus enabling the writers to layer a significant amount of new information into a few tightly-packed sentences. Students enjoyed marking up text to show the zigzagging pattern that emerges when a verb in one sentence is used as the noun topic in the next building the chain of logical meaning (Figure 1). For many students in this mixed EL-native speaker class, helping them decode this discourse feature was tantamount to giving them passports to a country previously closed to them.

Figure 1: Zigzagging Pattern of Verbs and Nominalizations

> As the heat increases, the salt will diffuse through the water.
>
> This diffusion results in a more concentrated solution.

Teaching the Language of Scientific Thinking

Once students were able to re-construct better the authors' intended meaning from lexically dense text, the teachers moved on to examining the ways language was used to convey key elements of scientific reasoning. After helping students identify the cognitive function achieved in a particular paragraph (e.g., relating a precise sequence, demonstrating cause and effect, effecting a comparison or contrast, expressing varying degrees of certainty), teachers led students through a discovery process to examine how that meaning was constructed. Students highlighted words and phrases that were instrumental in effecting the intended purpose, and listed those in separate 'language menus' for each cognitive function. These were posted in the room and the class added new examples as they encountered them in additional reading. By helping students to decode the meaning of these language structures and then later requiring their use in student writing, teachers were apprenticing students into both the cognitive processes and communication patterns of the scientific community.

Implications

Functional language analysis helps students decode the language of science and then express their own reasoning in scientific ways. While much of science teaching today emphasizes scientific inquiry and performance-based activities [7], developing a framework to approach scientific literacy through functional language analysis will move all students toward a more sophisticated understanding of scientific concepts. By apprenticing students into the language of science, we afford them opportunities to access higher levels of scientific knowledge and to participate as authentic members of the scientific community.

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Patterns in EL Students' Mathematics Course-Taking

In 2009, the results of the 2008 National Assessment of Educational Progress (NAEP) were released. Among the information collected from 17-year-old students were all the mathematics courses they had taken, including current course(s). Their choices included general, business, or consumer math; pre-algebra or introduction to algebra; algebra 1; algebra 2; geometry; trigonometry; and pre-calculus or calculus. The general trend for all NAEP-tested students shows larger percentages taking higher-level mathematics courses in 2008 as compared to previous years. Of interest here, data indicate that, in 2008, more ELs reported algebra as their highest math class, more nonELs[1] reported calculus as their highest-level math class; equal percentages of ELs and nonELs report Algebra 2 as their highest level math course. These data, shown graphically in Figure 1, demonstrate that ELs are not taking the math classes needed to be fully career-ready and college-prepared.

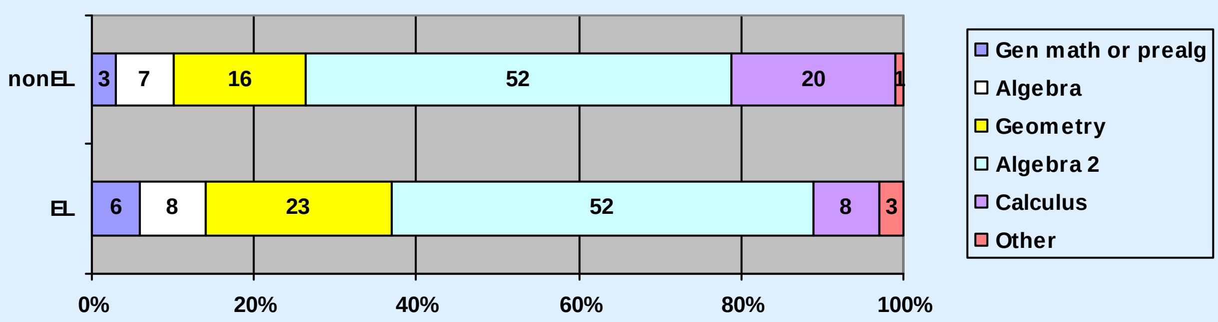

Figure 1. Trends in EL s Math Course-Taking. Based on NAEP data; retrieved May 5, 2009 from www.nces.ed.gov/nationsreportcard.

Notes

1.The "nonEL" group is made up of students who were never identified as EL and those who had attained English proficiency, who had entered a mainstream English-based classroom, and who had completed the Title III-mandated 2-year monitoring period.

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Tools of Systemic Functional Linguistics

Besides teaching vocabulary and using visuals, teachers need to teach EL students to "unpack" the dense writing of scientific texts. Systemic Functional Linguistics (SFL) provides useful analytical tools to recognize typical features of scientific writing. For example, scientific texts often use nominalization (turning verbs that describe processes into abstract nouns), modifiers (adjectives, adverbs, or clauses that provide additional information), and ellipses (the omission of word[s]).

As students progress in their study of abstract scientific concepts, the information often becomes more compact, and writers use nominalizations to shorten the text. For instance, a biology textbook's introduction to genetics states, "Mendel had charge of the monastery garden" [1, p. 182]. In this sentence, both "Mendel" and "the monastery garden" are participants in the process of Mendel being in charge. When Mendel fertilizes one plant with the pollen of another plant, this *process*, identified as "cross-pollination," becomes a *participant* in other processes such as forming seeds. Students may lose track of the processes behind abstract participants (represented by abstract nouns), and teachers should revisit the concepts often.

Pre-modifiers and post-modifiers are used before or after abstract nouns to provide additional information about participants answering questions such as, "which one? how many? what kind? what is it like?"[2, p. 29]. For example, as the discussion in the biology text turns to mitosis, the author writes, "In mitosis, the 8 chromosomes line up individually in the center of the cell. The two chromatids that make up each chromosome then separate from each other" [1, p. 194]. The numbers tell how many chromosomes and chromatids, respectively, are involved in this process. The clause, that follows "chromatids" provides more information about which chromatids separate—the ones "that make up each chromosome."

The ellipse, or the omission of one or more words, often is used in scientific texts to avoid repetition. The text cited above continues: "Each chromosome pairs with its corresponding homologous chromosome to form tetrads. The homologous chromosomes may exchange portions of their chromatids in a process called crossing-over." The second sentence in this example also could be written as, "These may exchange portions of their chromatids…" EL readers may need guidance to infer the missing word.

EL students will benefit from a teacher's explicit instruction in how nominalization, modifiers, and ellipses are used in scientific discourse and in how to use these features in their own writing.

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Challenges in Engineering Design as a Space for Language Development

Kevin Carr, Elizabeth Schlessman, and Ian Niktab

We were given 15 minutes a day for science this year. —4th Grade Teacher

Given the need for increased STEM literacy in the 21st century, the reduction of STEM teaching time for elementary school ELs is an alarming national trend [1; 2]. In this article, we illustrate how engineering design, implemented in a 5th grade dual-language immersion classroom, can provide a unique and motivating space for developing language forms and functions. We hope to encourage teachers to use STEM as a central focus for language development, providing enhanced STEM learning for ELs.

Science Inquiry, Engineering Design, and Language Functions

Engineering Design is part of our state's Academic Content Standards in Science [3]. Engineering design projects share elements in common with science inquiry (Table 1). The processes used while creating a working solution to a practical problem provide powerful opportunities for children to practice a variety of speaking and writing tasks. The hands-on, applied nature of engineering-design activities makes them accessible to students at beginning to advanced language levels.

Our western Oregon school district, whose elementary schools enroll over 75% ELs, has adopted Susana Dutro and Caroll Moran's "Form, Function, Fluency" formula for designing English-language instruction [4; 5]. Engineering design provides a rich opportunity for practice and application of a variety of language functions, developing both written and oral language fluency (see Table 2).

On Target: An Engineering Design Challenge in a 5th Grade Bilingual Classroom

On Target is an engineering design challenge based on NASA's 2010 LCROSS (Lunar Crater Observation and Sensing Satellite) moon mission [6]. LCROSS was designed to detect water ice lying under the surface of a permanently shadowed crater. The presence of significant water on the moon is critical for future lunar exploration. To check for water, LCROSS dropped a large projectile into a lunar crater, sending a plume of dust into space. LCROSS sensors scanned the resulting dust plume to detect the presence of water. *On Target* challenges students with a similar task: Create a device to drop a marble from a moving paper cup onto a sand target crater.

Table 1. Commonalities Between Science Inquiry and Engineering Design

Science Inquiry	Engineering Design
Articulate Questions	Define Problems
Explore Relevant Information	Explore Relevant Information
Explore Scientific Models	Brainstorm Solutions
Design Experiment	Create Possible Solution
Test Scientific Models	Test Solution
Make Meaning of Experiment	Refine Solution
Communicate and Apply New Model	Communicate and Apply New Innovation

Table 2. Engineering Design, Language Functions and Student Writing

Fluency Building Activities in Engineering Design	Language Functions	Sample Student Writing and Speaking
Define Problems	Defining	"My experiment was to make the marble to the sand because were doing a experiment about outer space."
Explore Relevant Information	Asking Informational Questions	"I still wonder if NASA is going to drop the Leftover Rocket. It it it's the moons creater what would have happened." "I still wonder if NASA would try it with some other type of thing that would be more easy for them?"
	Asking Clarifying Questions	"*Do we have to use the cup?*" "*What's the secret?*" "*Do you think it would work with a bowl of rice?*"
Brainstorm Solutions	Making Predictions	"*When you grab it, it will stop right here*" (gestures with hand)
	Hypothesizing and Speculating	"*If it went higher it would gradually tip.*"
	Persuading	"*Cool, why don't you just let this go and like, let the whole thing wham it?*"
Testing and Refining Solution	Describing	"I'm put the marble on the cup and my grup put string, paper clip, plate, chair, me take one cup and puted on the string."
	Drawing Conclusions	"At first I tried it and I missed because I did not pulled the string." "*I got an idea when I took this off* (points) *and it worked.*"
Refine solution	Making Predictions	"*I have an idea…if you put this there, it would tip over like this…*" "*I thought of a new way and I hope it works.*"
	Hypothesizing and Speculating	"*This is what I found out because when I was trying it with only one it didn't fall and when I did three more it started falling because of the weight.*"
Communicate and Apply New Innovation	Retelling	"When we tried to land the marble in the plate of sand. I tryed it more than 3 times but it didn't work." "One problem we had to solve was aim at the middle and make it work." "I thought of puting string half way on the cup, then when it was half way I pulled it and fell into the moon."
	Describing Things, Actions, and Temporal Relations	"In my class my teacher was amaised how I work so hard."
	Cause and Effect	"I made it too much hole I think that's why it didn't work."

Students are supplied with string, cups, tape, paper clips, a marble, and a pie plate filled with sand. The cup slides down an inclined zip line for approximately 10 feet prior to the point at which the marble is released (Figure 1). The 24 students in our 5th grade dual-language classroom first explored LCROSS and the *On Target* challenge by discussing the question "What supplies would we need in order to live on the moon?" Students brainstormed a list of supplies such as "shelter," "fuel," "food," "water," etc. Students were told that transporting items to space is very expensive, so we would want to use supplies found on the moon as often as possible. Water is a necessity and very common in the solar system, but is heavy and expensive to transport to space. The students then viewed a NASA video designed to orient students to the goal of LCROSS (to find water on the moon), and to the main components of the LCROSS mission [7].

In the lesson's second session, students worked in small groups of 3-4 on the *On Target* design challenge (Figure 2). Students spent over an hour brainstorming, creating, testing, and refining possible solutions, while teachers circulated among the groups, helping them to clarify their own ideas and theories. Each group demonstrated and explained to the whole group how they came to their final solution. Afterward, students wrote in their "science journals" about the design challenge, creating diagrams and using complete sentences to explain how they solved the problem, what challenges they had, and what questions remained (Figure 3).

Practicing Language Functions

To document student language practice, we collected written journal entries and videotaped student conversation. *On Target* motivated students to use a number of language functions in both speech and writing, allowing teachers to document and diagnose language usage (Table 2). Teachers are able to intervene verbally in real time, and in post-writing conferences with students.

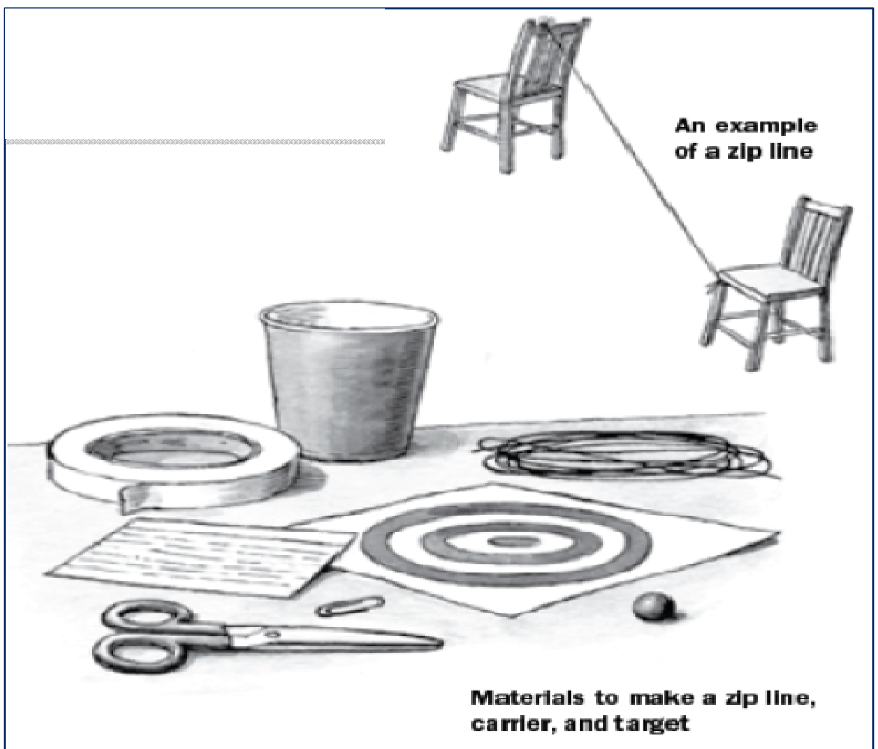
From Either-Or to Both-And

STEM education often is disconnected from language and literacy learning. The result is less time for STEM instruction, especially for those ELs for whom academic literacy is of primary importance. In our experience, rich engineering design challenges such as *On Target* motivate students to practice academic-level language forms and functions, while also providing teachers with opportunities for corrective intervention. Research shows that student language development is enhanced by intentional integration into engaging STEM tasks [5]. Planning for STEM instruction as *both* a subject area *and* a space for language learning has makes possible the allocation of significant time—four hours or more/week—to STEM teaching while simultaneously engaging language development.

Notes

1. Thanks to Catherine Kim, and Karren Timmermans for assistance with this project.

Figure 1. Materials and Sample Designs from On-Target Teacher Materials [6]



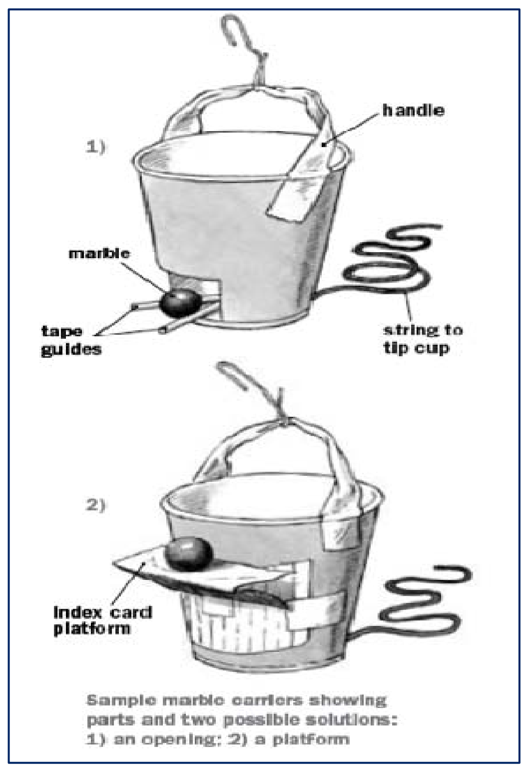


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Figure 2. Accessing Materials and Working in Groups

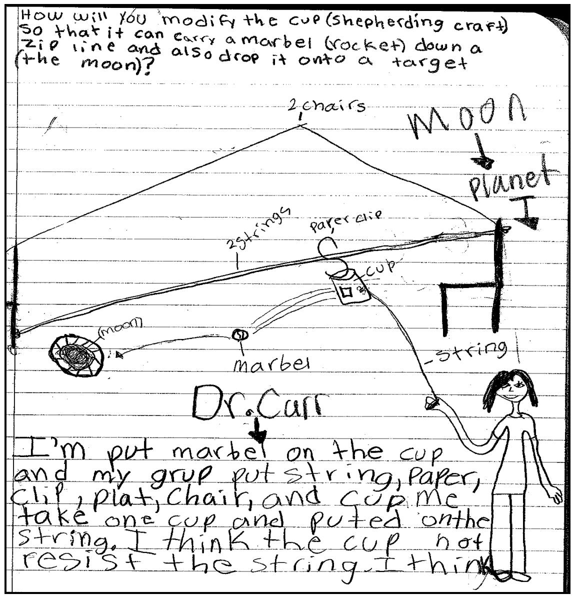

Figure 3. Student Journal Entry

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Innovative Solutions to Help Teachers of ELs in a Math and Science Classroom

The Peer Enabled Restructured Classroom (PERC) is a research-based model that works to meet the needs of all learners in the complex science and mathematics high school classroom. PERC is a promising alternative to traditional classrooms that develops an effective community of learners, enabling a truly student-centered classroom to emerge through many avenues, including daily peer-led group work. The PERC classroom organizes students into interdependent groups led by trained peers, Teaching Assistant Scholars (TAS). The teacher carefully plans appropriate, differentiated learning experiences for the students, which the TAS implement. The teacher mentors the TAS, manages the learning environment, assesses student understanding, and plans effective responses to student needs. The TAS, who are integral to the success of the model, are high school students, most of whom are themselves former ELs (F-ELs) who passed the course and the end-of-year state exam at a level that is predictive of college remediation. They take a daily "TAS class" with the PERC teacher to learn pedagogical strategies, advanced content, and college preparedness. In addition to supporting the success of the 9th grade students, the performance of the TAS themselves improves dramatically throughout the year, enabling them to succeed in advanced coursework and avoid future remediation. Integral to this project is the introduction and teaching of literacy strategies necessary for success in difficult academic content material [1; 2; 3] to the TAS and PERC students. These literacy strategies are incorporated into the content teaching and are introduced, modeled, demonstrated, monitored, and observed by project investigators. Through two years of quantitative (test results) and qualitative (observations, interviews, survey, and focus groups) research, the PERC model has shown benefits to ELs and F-ELS in secondary math and science content learning [4]: it facilitates connectedness and self-confidence, increases motivation, and develops ability to negotiate and engage the content more effectively.

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Helping ELs Reason Mathematically through Explicit Language Moves: Towards Meaningful Participation

Zenaida Aguirre-Muñoz

Although standards-based reform was intended to close persistent achievement gaps and lead towards greater educational equity, the introduction of high-stakes testing has resulted in a trend toward narrowing curricula which may grossly limit ELs' learning opportunities [1]. The shift in learning opportunities stems, in part, from teachers' insufficient knowledge of the content *in relation to* students' cultural and linguistic diversity [2; 3]. Standardized curricula simply cannot predict every potential student response to instruction - responses upon which teachers base their moment-by-moment interactions with students. Drawing on a substantial body of work from the learning sciences (sociocultural and situated learning theory), we contend that it is through these moment-by-moment interactions with students that teachers can develop ELs' critical thinking skills, particularly mathematical reasoning [4]. This paper describes the innovative work conducted as part of a larger project aimed at developing teachers' knowledge of teaching mathematics.[1]

Scaffold the Unpredictable

Central to teaching approaches that target the development of ELs' higher-order thinking skills is the explicit planning and incorporation of supports or scaffolds, distinct from simply helping students complete tasks they cannot do independently [5], that allow students to maximize their learning potential [6]. While scaffolding discussions tend to focus on the design or more predictable aspects of instruction, scaffolding also happens when new and unpredictable behaviors emerge and the teacher channels and stimulates the student's ongoing responses and behaviors, making it possible to maximize growth potential [6]. A teacher who scaffolds successfully through both task design and *feedback to students* (the predictable and unpredictable) can identify signs of an emerging new skill and and use that skill to engage the student in higher-level functioning. Two promising approaches for scaffolding mathematical reasoning are questioning and language moves that model cognitive processes.

Language Moves that Scaffold Mathematical Reasoning

Thinking Questions. Asking good questions improves the overall quality of instruction. Appropriate questioning techniques help students to make sense of math concepts while developing their conceptual understanding, because they reveal and monitor what students know and understand. Students also become more comfortable with multiple ways of using important math ideas because they are rewarded for posing multiple solutions based on alternative, accurate math reasoning. Three types of questions are particularly suited for monitoring mathematical understanding and reasoning while increasing the proportion of students who remain engaged in math conversations [7]:
(1) engaging questions, (2) refocusing questions, and (3) clarifying questions (Table 1). Using different kinds of questions for different purposes helps to differentiate instruction and tailors instruction to the specific needs of students.

Talking Mathematics. Training teachers to ask certain kinds of questions, however, may not provide sufficiently explicit information for ELs about valued ways of knowing and interacting in math classrooms. An additional challenge in teaching mathematics is developing a sense of significance in "doing math." Past research demonstrates that students must understand that math is a process of thinking and reasoning rather than a set of steps to go through to get the correct answer [8]. ELs need explicit instruction in *articulating principles*, not just focusing on the description, sequence, and choice that are more practical aspects of math knowledge [9]. One strategy for scaffolding principled math discussions to ELs is using language to explicitly model ways of thinking and reasoning about mathematics [10]. Language modeling enables ELs to adopt ways of "talking mathematics" that are valued by and important to the mathematical community [11]. Strategies that make the language of math reasoning transparent to students enable teachers to develop and reinforce norms for talking mathematics in valued ways. Over time, students appropriate these ways of doing and talking mathematics, thereby affecting students' math beliefs and self-efficacy [12].

Researchers have identified two important ways teachers expose students to modeling that directs their attention to valued ways of talking and thinking about math principles and relationships between concepts: *stepping out* and *revoicing*. Stepping out refers to more explicit language moves such as reflection on math actions or talking about math. The teacher momentarily 'steps out' of the discussion to explicitly state thought processes and questions that need to be asked while solving a math problem or identifying aspects of an appropriate mathematical explanation. Revoicing refers to less explicit language moves that allow the teacher to reformulate a student's response by either clarifying or extending what a student has said. It is a way for the teacher to clarify students' statements, make connections, or fill in missing elements of an explanation, thus helping other students to understand the significance of the contribution.

Table 1. Definitions & Examples of Thinking Questions & Language Moves that Develop Math Reasoning

Type	Definition	Example
Thinking Questions		
Engaging	Invite students into discussion, keep them engaged in conversation, and invite them to share their work. Open-ended with multiple acceptable answers.	*How can we decide what kind of word problem this is?*
Refocusing	Get students back on track or to move away from a dead-end strategy. Direct students to some important aspect of a problem they may be overlooking.	[to focus on the definition of ***congruent***] *What does it mean for two triangles to be congruent?*
Clarifying	Help students explain their thinking. Help teachers understand students' thinking.	*How did you determine that those triangles are congruent?* *How did you get X?*
Language Moves		
Stepping Out	Step momentarily aside from the discussion to explicitly state thought processes. Teacher 'thinks aloud' as she is working a problem that highlights cognitive processes.	*When I read this word problem, what question should I be asking inside my head to start the problem?* *If I look at the word 'total' that means addition…wait, I need to first make sense of the problem. The total number currently enrolled is not the same as initially enrolled. I know this because some people have withdrawn …* [teacher highlights other important aspects of the word problem] *so this problem has multiple steps involving subtracting and addition…*
Revoicing	Reformulate a student's response by clarifying or extending what was said, making connections, or filling in missing elements of an explanation.	Student: Um, I just, um, divided by one-third. *Teacher**:** Divided both sides by one-third. What's one-third divided by one-third? One, right? Something divided by itself. When I divide twelve by one-third, dividing by a fraction is the same as multiplying by its reciprocal. So twelve times three would give me thirty-six.*

Making language transparent is a complex process, especially for teachers who work with ELs. In our work with math teachers, questioning and talking mathematics are developed by engaging teachers in structured self-reflection, using language move forms (Figure 1), that have helped math teachers improve their teacher talk to develop math reasoning and to promote meaningful participation.

Conclusion & Call to Action

Classroom interaction is a unique way of giving all students opportunities to observe math reasoning in action and to develop their own abilities with math reasoning. When teachers make language moves a regular feature of their teaching and interactions, it sends the message that math is flexible, makes sense and has meaning, requires reason for its procedures, and requires particular kinds of explanations [11]. We challenge mathematics teachers who read this article to try these language moves in their classrooms. Do your language moves clarify math reasoning to ELs and move toward constructing meaningful math learning for students? You can download a guide describing these techniques in detail, and access forms at http://www.wtmsmp.math.ttu.edu/ProjectActivities.htm.

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1. The project was funded by the National Science Foundation.

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Figure 1. Sample Language Move Form Used with Math Teachers

Investigating Your Questioning This form can be used to document your questioning as you listen to the recording of your lesson. When you hear yourself asking questions, note when they occur, how students respond, and how you follow up. Number each occurrence so you can follow it in the third column.		
Question Types	When It Occurs	How Students Respond How You Followed Up
Engaging Questions *Listen for how you started your lesson, when you re-directed students who were not engaged in the discussion.*		
Refocusing Questions *Listen for times when you asked students about the strategy they used.*		
Clarifying Questions *Listen for times when you ask students to give reasons for their answers or to explain what they are doing or thinking.*		

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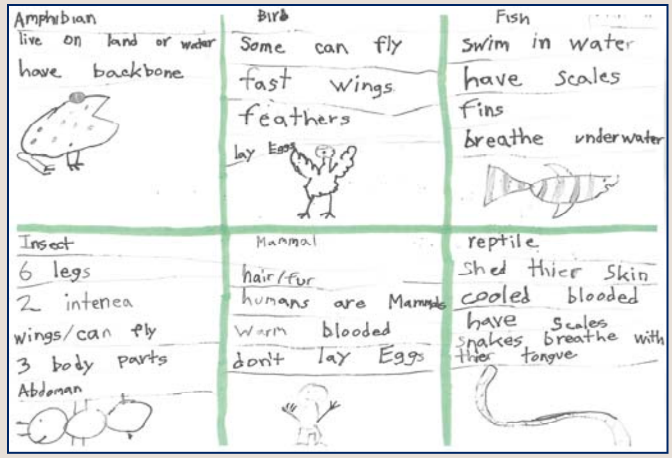
Ideas for AccELLerate!

As the National Clearinghouse for English Language Acquisition (NCELA) moves into another year, we want to be sure that we are meeting your needs, and providing information on topics of interest to you. Is there a topic that you would like to see be the focus of an issue of AccELLerate! ? Are there specific authors or areas within the topic that you would like to suggest to us? If so, please contact the AccELLerate! editor, Natalia Romanova, by email: romanova@gwu.edu. To review topics that have been in previous issues, please go to the NCELA website: http://www.ncela.gwu.edu/accellerate/

Building Early Elementary ELs' Scientific Content Knowledge and Inquiry and Literacy Skills

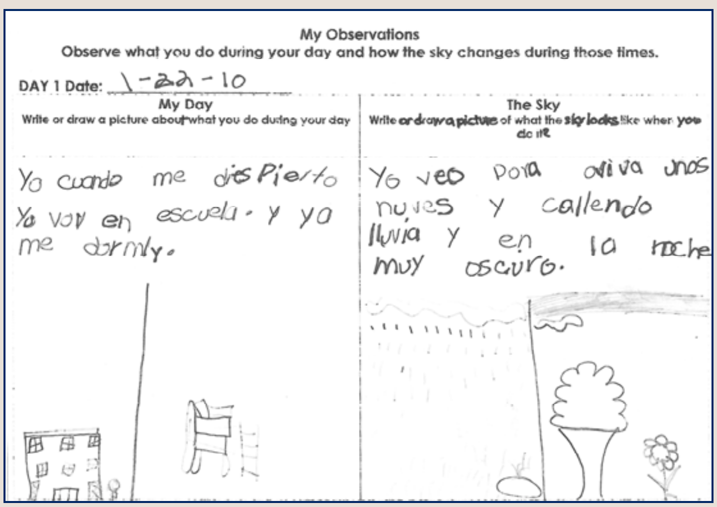
Emiliano Zapata Elementary Academy, a public school in Chicago, IL, prepares students to learn and excel in the 21st century through an engaging yet rigorous academic program. Over 99% of the 855 students enrolled at Zapata are Hispanic, about 98% are from low income homes, and about 52% are designated as ELs. Zapata's leaders know that teaching science content and process skills beginning in the early grades increases students' background knowledge, nurtures their curiosity, and builds a solid foundation for future science learning.

Figure 1. EL's Science Notebook Content and Vocabulary Entry



During the 2009–10 school year, Zapata's second grade classes participated in a randomized, controlled trial efficacy study of a core science program for elementary students, *National Geographic Science (NG Science)*.[1] The comprehensive science program aligns with the National Science Teachers' Association's (NSTA) research-based guidelines for science for ELs [1], integrates content and inquiry skills in ways that promote an accurate understanding of science, and encourages students to "think like scientists" as they learn standards-based science content. ELs were engaged in a variety of experiences with science concepts and were provided differentiated instruction supports (e.g., detailed visuals, videos, leveled texts, big idea cards, vocabulary cards) to ensure that they mastered grade-level science objectives through multiple experiences with content. Graphic organizers (e.g., KWL charts) and creating "I learned/I wonder" charts helped ELs make sense of complex information and science vocabulary. To deepen their understanding of scientific concepts and build language skills, students worked in collaborative teams to conduct hands-on leveled inquiry investigations [2], participated in discussions, made predictions, carried out steps, recorded observations, collected and analyzed data, and shared their conclusions. They documented their scientific experiences, formulated their own ideas, and made connections to prior learning in science notebooks [3] that were used by teachers to gauge their comprehension, both in content and in language, and to help determine future science and language teaching points (Figures 1 and 2). ELs read leveled books related to science "big ideas," and shared what they had learned with classmates (e.g., the habitat unit has leveled books on ocean, prairie, and desert habitats) which helped ELs develop academic literacy in English [4].

Figure 2. EL's Science Notebook Observations about the Weather



Assessments including reading, science content, and science inquiry skill measures, showed that students using *NG Science* outperformed students in the control group that continued with existing school-created science materials, by gaining nine scale score points more in Word Knowledge on the Gates-MacGintie Reading Test (GMRT) and demonstrating significantly more 'informed' views of the Nature of Science and Science Inquiry on the Young Children's Views of Science (YCVS) assessment.

Notes

1. The study, conducted by Magnolia Consulting, investigated a comprehensive core science program from National Geographic School Publishing for students in grades K-5.

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Science and Vocabulary for English Learners

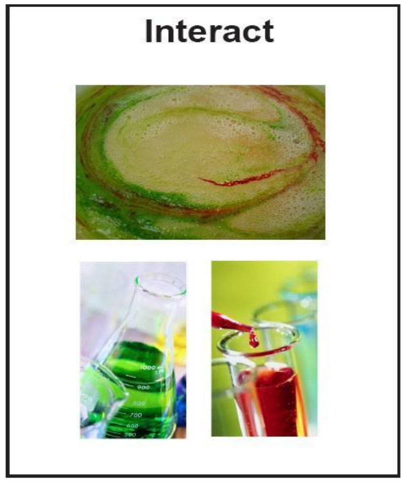
Diane August, Lauren Artzi, and Julie Mazrum

Current educational policy embodied by the *ESEA* requires that all students, including ELs, meet high standards in science, language arts, and math. While expectations for content area achievement are high, findings from the National Center for Education Statistics [1] indicate that scores at all grade levels are considerably lower for ELs than for their English-proficient peers. This article describes two interventions that succeeded in improving academic and discipline-specific vocabulary and science knowledge in ELs by building on effective science and language arts methods used for teaching native English-speaking students, but making adaptations that consider the needs and strengths of ELs [2; 3]. Both studies were conducted in a Texas school district with a high percentage of Latino ELs through CREATE, a federally-funded research center that focuses on educating ELs in the middle grades.

One intervention focused on developing third and fourth graders' general academic and discipline-specific language associated with science lessons and consisted of a 60-minute language arts add-on to a summer school science enrichment program that used the Full Option Science System (FOSS) materials. To develop students' general academic and science vocabulary, teachers pre-taught vocabulary using vocabulary cards with pictures to demonstrate the words. Definitions were provided in both English and Spanish, and students were taught to draw on cognate knowledge. Teachers explained how a picture demonstrated the concept being taught. An example of the vocabulary card is shown in Figures 1 and 2.

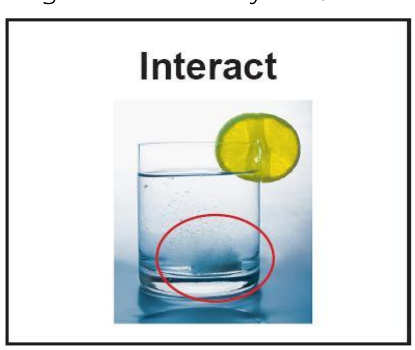
First, the teacher showed the front of the card (Figure 1). Then the teacher said the following:

Figure 1: Vocabulary card, side 1



1. A word in the text is "interact." When two things interact, they have an effect on, or change, each other.
2. En español "interact" quiere decir interactuar. Cuando dos cosas interactúan, tienen un efecto sobre, o causan un cambio hacia, cada cosa.
3."Interact" in English and "interactuar" in Spanish are cognates.
4. Now, let's look at a picture that demonstrates the word "interact." When these two liquids [point to the green and the red liquids in the bottom pictures] are mixed together, they interact with each other. Their colors will change, and they will also produce bubbles [point to the top picture]. Then, the teacher showed the reverse side of the card (Figure 2), which included a second picture of the concept, and asked students to turn to a partner and explain how the new picture demonstrated the word's meaning.

Figure 2. Vocabulary card, side 2



Pre-reading activities consisted of a picture walk through the text and a "hook" question addressing the central concept of the lesson. The teacher and students engaged in shared interactive reading, discussing text written by the investigators to reinforce the science concepts in the FOSS lesson, and students answered questions that required using the targeted vocabulary. Glossaries, concept maps, and review games reinforced the targeted vocabulary. Results show that students (all ELs) performed significantly better on the posttest on vocabulary explicitly taught using intervention methods than on vocabulary they were simply exposed to.

The second intervention was part of Quality English and Science Teaching (QuEST), a project designed to develop the science knowledge and academic language of ELs and their English-proficient classmates in the middle grades. A guiding principle of this study was the importance of making science instruction effective for both ELs and English-proficient students, because they often learn together. Thus the intervention was grounded in research on high-quality science instruction in the middle grades. Development also drew on research about the role of ELP, learning in a second language, and knowledge acquired in the first language (in this case Spanish) to tailor the interventions to the language and literacy needs of ELs. The intervention built on the district curriculum, using the Prentice Hall textbooks and workbooks, as well as district-developed labs aligned with them, but it also incorporated additional components oriented toward developing ELs' language proficiency and helping ensure they understood the science content that was delivered in mainstream classrooms. To this end, the intervention included direct instruction of both general and discipline-specific vocabulary. Definitions were provided in students' first and second languages, and students were taught to draw on cognate knowledge.

The QuEST intervention used scaffolding techniques that foster ELs' understanding of academic content [4]. Visuals were consistently used in science lessons, including illustrations of concepts and graphic organizers. Teachers previewed the experiments that students would conduct to ensure that they understood the goals and procedures. Teachers were shown how to engage in instructional conversations during science tasks and while reading the textbook to support development of students' conceptual knowledge and oral proficiency [5]. They were encouraged to have students with very limited ELP respond in their first language and to interpret or have a classmate interpret their responses into English.

Posttest results of students who had received the intervention showed statistically significant improvement over those who had not, for both science knowledge and vocabulary.

Both interventions were effective in developing the academic vocabulary of ELs. The QuEST intervention, which also focused on building science knowledge, was successful in accomplishing this goal [6]. This research demonstrates that combining good science teaching with scaffolding and a focus on language development is effective for helping ELs improve academic and discipline-specific vocabulary and content knowledge.

Acknowledgments

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Web Resources: Math and Science for ELs

Math and Science

- NCELA (2009). *AccELLerate! Volume 2, Issue 1*. This issue was dedicated to math and science literacy for ELs. http://www.ncela.gwu.edu/files/uploads/17/Accellerate_2_1.pdf
- NCELA (2011). Resources for Preparing Teachers of Science and Mathematics to Work with English Learners. This 2011 guide from NCELA provides a summary of research findings and best practices emerging from literature on teaching math and science to ELs, as well as practitioner and professional development resources. http://www.ncela.gwu.edu/files/uploads/9/NCELA_STEM_2011.pdf

Math

- Bright, A. & Dominguez, A. (2009). *What Teachers Need to Know to Assist ELLs in Math*.. This webinar presents an overview of the FAST mathematics program, which emphasizes a dual focus on English language acquisition and mathematics.http://www.ncela.gwu.edu/files/webinars/14/Webinar_2%20full%20presentation.pdf
- National Council of Teachers of Mathematics: http://www.nctm.org/.This website has many resources on a variety of topics related to ELs and math that can be found using "English learners" as key words. The site also provides NCTM's official position on teaching math to ELs: http://www.nctm.org/about/content.aspx?id=16135.
- Texas State University System's Mathematics for English Language Learners (TSUSMELL). TSUSMELL provides a list of useful web resources and lesson plans for math teachers of ELs: http://www.tsusmell.org/resources/useful-links.htm.

Science

- National Science Teachers Association. This website provides the NSTA's official position on teaching science to ELs: http://www.nsta.org/about/positions/ell.aspx,. In addition, publications, products for purchase, conferences, and NSTA recommendations can be accessed through the main website page through a simple search: http://www.nsta.org

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Sharing our Success in Math

Because my large public school district (Fairfax County Public Schools, in Virginia) is home to approximately 35,000 English learners in our K-12 schools (as part of a total school population of around 165,000 students), there exists a strong need for teachers to be well prepared to meet the needs of ELs in mathematics at all levels. Our students represent a broad range on many axes, in that we have over 180 countries and greater than 200 language groups represented. Although many English learners in our district were born in the United States, many began their formal educational experiences outside the U.S., and come with a range of experiences. A small subset of our learners have limited or interrupted formal education, and in some cases, enter school for the first time as newly-arrived adolescents here in our district.

In spite of the robust and well-educated pool of teachers in the school district, the majority of educators were never formally prepared to tailor their instructional approaches to support language learners in mathematics. To this end, Fairfax County Public Schools has funded two full-time positions that focus exclusively on mathematics education for English learners: one at the K-6 level, and one at the 7-12 level. These teachers offer guidance not only to mathematics teachers with ELs in their classes, but to ESOL teachers with sheltered mathematics classes. I have worked as the 7-12 support teacher for the last 7 years.

Students entering our school district first visit an Entry Assessment Center, where they are evaluated for their level of English proficiency and are also assessed (in L1, if possible) for a general idea of their mathematics background. Because we recognize that mathematics is taught in different orders in different parts of the world, this broad assessment (consisting of 96 items) provides a baseline for determining which course might be most appropriate for each student, and also provides formative information about what skills students already know. We currently have around 40 different translations of the mathematics assessment that meet the needs of the majority of newcomers to our district.

Our students with strong backgrounds in mathematics are enrolled in grade-appropriate mathematics courses, even if they are at the beginning levels of English. The expectation is that our mathematics teachers will differentiate instruction in ways that support their students, which may include providing comprehensible input, using multiple real-life models and manipulatives, and providing rich and authentic opportunities for students to practice using new vocabulary and language to communicate mathematically. For our teachers who struggle with these concepts, I serve as a support person, providing in-service workshops, one-on-one support, and model lessons, along with adapted and scaffolded materials.

For our students with limited or interrupted formal schooling and gaps in their mathematics understandings, our district has created a sheltered mathematics course that is loosely modeled on the SIOP format. Originally funded by a multi-year Title III grant, the curriculum, called FAST Math, is intended for students who are working at least two years below their same-grade-level peers, and who are also at the beginning levels of English. Built around the Grade 7 mathematics curriculum, the primary goal of this course is to prepare the students (who may be in grades 7 -12) for entry into Algebra 1. Using an approach that includes both mathematics and the English that accompanies mathematics, teachers use a series of scaffolded pre-assessments that align to the various units throughout the year—equations, statistics, measurement, and so on. With the teachers of these sheltered courses, I provide assistance in understanding how to teach the mathematics content at hand. We recognize that although not all students are prepared to dive into Grade 7 mathematics content, each student is working at some point along a continuum of readiness for that content, and the pre-assessments help to identify these areas.

As an example, during the unit on measures of central tendency, we recognize that not all students are prepared to calculate the mean of a set of numbers. The pre-assessment includes simple items that focus on the component parts of the skill: counting, placing numbers in order form smallest to largest, adding, subtracting, and dividing. Any areas where students are unsure can be explored through interactive, manipulative, language-rich activities our teachers access online.

In short, Fairfax County Public Schools has shown innovation and commitment in working collaboratively to meet the unique needs of the language learners in our care in mathematics. We are eager to share our successes and to continue to improve our collaborative professional practice.

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Note: Fairfax County's FAST Math curriculum is available online at http://www.ncela.gwu.edu/faqs/view/13.

Academic Vocabulary Instruction within Inquiry Science: The Blended/Tiered Approach

David T. Crowther, Erin Tibbs, Rebecca Wallstrum, Elisa Storke and Bernadette Leonis

"Without grammar very little can be conveyed, without vocabulary nothing can be conveyed." —Wilkins, 1972 , p. 228 [1]

Language plays a significant role in STEM learning, yet it is the use of this scientific language that is the principal barrier to conceptual understanding for ELs. The language of science is highly complex and requires students' precise understanding of very specialized vocabulary to carry out common scientific tasks. Most vocabulary research focused on SLA recommends that teachers use a Direct Instruction (DI) approach and advocates frontloading the majority of technical words, providing students with the vocabulary prior to most content instruction.

However, the inquiry approach [2] advocated by the National Science Education Standards [3; 4] can be an effective way of teaching ELs both content and vocabulary by allowing them to experience the phenomena first and then learning the associated academic vocabulary after the experience. Inquiry instruction typically involves students in asking questions, solving problems through both cognitive (minds-on) and kinesthetic (hands-on) experiences, and making discoveries of the content through the experience in order to formulate conclusions. This paper describes an inquiry approach to teaching science vocabulary within a 5E (Engagement, Exploration, Explanation, Elaboration, and Evaluation) lesson design [5; 6].

The Blended/Tiered Vocabulary Approach

Vocabulary is classified into a three-tier system [7]. The first tier consists of the most basic words—8,000 word families that require little or no instructional attention in school, that could be called acquired vocabulary [8] or Basic Interpersonal Communication Skills (BICS) [9; 10]. The second tier consists of high-frequency words—7,000 word families—used in academic settings (e.g., *observe* and *investigate)*. Lastly, tier 3 is comprised of words with very low frequency that are often limited to specific domains and would be considered highly academic and content-specific (e.g., *isotope* and *photosynthesis*) in any language [6]. The tier 3 words can be thought of as part of Cognitive Academic Language Proficiency (CALP) [9; 10].

The three-tiered classification of vocabulary is a valuable guide for teachers in the science classroom. To increase the efficacy of teaching the language of science, teachers must be able to scaffold vocabulary instruction across a learning cycle. Typical Sheltered Instruction (SI) models (e.g., Sheltered Instruction Observation Protocol, or SIOP) [11] or the Guided Language Acquisition Design, or GLAD [12]), utilize either frontloading only or a combination of 80% frontloading and 20% contextualization as a common strategy for vocabulary instruction or scaffolding vocabulary under a DI model. However, within an inquiry science lesson, blending vocabulary instruction, or a combination of frontloading and contextualizing vocabulary instruction, seem to make more sense than frontloading vocabulary as the goal of the inquiry is to discover the content through an experience that then can be labeled by new vocabulary terminology [13]. Several studies explore various combinations of frontloading and contextualization of vocabulary, and, contrary to what typically is done in DI, a blend of 20% frontloading and 80% contextualization of vocabulary instruction has been found to optimize vocabulary instruction over contextualizing only and frontloading only [14; 15]. Table 1 shows how tiered vocabulary is distributed over an inquiry science lesson utilizing the 5E learning cycle [5]:

(1) During the Engagement and Exploration phases of the learning cycle, tier 1 and tier 2 words are used to frontload 20% of the vocabulary;

(2) During the Exploration phase, the other 80% of the vocabulary is introduced and formalized using tier 3 words for discussion, questions and answers, use of notebooks, and word walls [16];

(3) During the Elaboration activity, students use the newly formalized tier 3 words as they engage with the phenomena; and

(4) Finally, in the summative evaluation, both the conceptual and related tier 3 vocabulary is assessed to measure student learning.

Table 1. The Distribution of Formal Vocabulary Instruction Over a 5E Learning Cycle Using Blended/Tiered Vocabulary.

BICS	BICS to some CALP (transition)	CALP
Tier 1 10%	Tier 2 10%	Tier 3 80%
Engagement	Engagement Exploration	Explanation, (formalized) Elaboration, Evaluation

A Closer Look at Blended/Tiered Vocabulary in a 5E Inquiry

Pre-Planning Phase:

1. Use the planning grid to help with the content and vocabulary planning process (Figure 1).
2. Identify both the content and process standard(s) the lesson will be addressing.
3. Identify the target "tier 3" vocabulary words in the lesson you will be covering. These are easy to recognize as they are highlighted in the text and stated in the standards.

	Tier 1 (BICS) Engagement & Exploration	Tier 2 (BICS / CALP) Engagement & Exploration	Tier 3 (CALP) Explanation, Elaboration & Evaluation	Word Definition
Content Standard				
Process Standard				

Figure 1. Standards & Vocabulary Lesson Scaffolding Planning Chart

4. Fill in the definition for each word you will be using or expecting your students to master.
5. Consider the language abilities of the students in the classroom as you think of simpler words that correspond with the tier 3 word at the tier 1 and 2 levels. For example, if *precipitation* was your tier three vocabulary word, simpler terms may include *water* or *rain*.

Lesson Planning/Teaching Phase: After preparing the tiered vocabulary table based upon the standards, the teacher has an outline of how the vocabulary will be scaffolded for the lesson. Utilizing the 5E model, a lesson now can be designed.

1. Engagement: The purpose of the engagement is to activate background knowledge by setting a context for the lesson and to get students interested in the lesson. In order to set a context the teacher may plan something simple based upon tier 1 words, which accomplish this task. A children's book, scenario, or short discussion may serve effectively to allow students to share background information and prior knowledge, which establishes tier 1 vocabulary naturally.

2. Exploration: The teacher then plans an inquiry activity, based upon the standards, that is both hands-on and minds-on . During this activity, children are encouraged to use tier 1 vocabulary, and the teacher may introduce tier 2 vocabulary that furthers their conceptual understanding. The teacher encourages oral communication between students and may use a science notebook for children to make drawings, observations, and simple notations.

3. Explanation: The explanation phase is where the teacher debriefs the content of the exploration activity and then introduces the tier 3 vocabulary using strategies such as word strips or a word wall. As the experience is discussed, children are allowed to use their tier 1 and 2 words. An example that we use in some of our research includes students using science notebooks and completing a table where they work with the teacher and peers to explore the relationship of the tier 1-3 vocabulary (Figure 2). The students are asked to draw or give a visual representation in column one, write their "everyday words" (tier 1 and 2) in column two, the "science word" in column three, and the definition in the last column. The definition is created by the students with the teacher's help to ensure that it is based on appropriate standards.

4. Elaboration: The elaboration phase is where the students engage with another hands-on /minds-on activity and practice both the newly learned content and tier 3 vocabulary.

5. Evaluation: The summative evaluation phase allows students to demonstrate their command of both the content and vocabulary of the lesson. We advocate using multiple assessments, including alternative assessments using science notebooks, in order for students to demonstrate their conceptual understanding through illustrations and labels (e.g., tier 1-3 words and simple sentences).

Conclusions

The blended/tiered vocabulary approach has been used in several different school settings with a variety of grade levels and EL proficiencies. Our research shows a statistically significant pattern in students' learning and retention of tier 3 vocabulary, especially for ELs, as compared to frontloading and traditional DI models of learning science [14; 15; 16].

The best illustration of the effectiveness of this strategy comes from a reflection by a fourth grade teacher on a lesson about the earth: "In the post-assessment the students showed huge growth in their knowledge of the definitions of most all tier three vocabulary words, and were able to apply those words to the content through illustrations and labeling. I noticed in many of the definitions students were using the tier one and two words to help them define the tier three word. For example, in defining *mantle* a student wrote, "*the mantle is a thick layer that comes after the outer core, it also has* **melted rocks**." For the *crust* a student wrote, "*the crust is thin it's made of* **land and water**. *It's the very top layer of the Earth*." In these examples, the words *melted rock*s were used to define *mantle* and *land and water* were used to help define *crust*. Having used the tier one and two words prior to formalizing academic vocabulary helped the students' transition from social language into academic language.

Picture	Common Word	Science Word	Definition

Figure 2. Science Notebook Strategy

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Using Technology to Improve Academic Vocabulary Development in STEM Classrooms

The academic vocabulary of STEM presents significant challenges for all students, but particularly ELs. The integration of hypermedia environments into STEM curricula is one way teachers can address this challenge. Examples of such environments that support linking graphics, sound, and video elements in addition to text elements include web-based tools such as *Visual Thesaurus, Word Clouds*, and *Online Encyclopedia;* Web 2.0 tools such as wikis and blogs; *Interactive White Boards (IWB)*; and hyperlinked *PowerPoint*. These environments can be tailored to meet the needs of ELs by incorporating an appropriate amount of text for the language level of the students and by adding images and sounds. Hypermedia environments also provide students with multiple opportunities for language production, task engagement, and academic vocabulary development [1; 2; 3]. In addition, hypermedia authoring tools, which afford teachers the ability to place the learner in an interactive, contextualized learning environment, allow students to interact with peers and design their own hypermedia environments. Students can encounter realistic problem situations and choose pathways and strategies for problem resolution. Such learner-centered instructional programming changes the role of the student from passive recipient of information to active learner choosing instructional resources and methods of learning. In general, these environments promote the use of cognitive and metacognitive learning strategies as students decide how to represent information and what associations to make between the text they are reading and the multimedia component they are utilizing [4], as well as facilitate vocabulary and concept development as students connect new words to their prior knowledge and choose their own words and images to represent the underlying concepts. Furthermore, through the use of technology, students can design multimedia presentations and technology-infused projects that encourage meaningful applications of new knowledge. Not only can various language development needs be addressed simultaneously by promoting the use of visually engaging and language rich technologies, the ability to use these environments encompasses many of the technology skills students need as they graduate from high school and work toward future careers.

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Using Vocabulary Foldables as a Vehicle for Authentic Math Assessment

"The students that don't speak English can never show me what they know. How can they, if they don't speak the language!"

—Middle School Teacher

Recently, we had the pleasure of observing a middle school math classroom, where we marveled at the teacher's implementation of the Vocabulary Foldable strategy [1; 2]. A Vocabulary Foldable (Figure 1)is a visual, kinesthetic tool that is designed to aid students' organization of lesson content while supporting their connections to background knowledge. The foldable consists of 3-4 pieces of colored paper stapled into a booklet. The pieces are offset by about a half inch so that the booklet has a colored tab for each page. Students use the tab to record the vocabulary item, and use the rest of the page for further exploration of the word. The booklet can be used before the lesson to assess the students' level of understanding by asking them to record their ideas in relation to new concepts or ideas that will be covered. During instruction, students add their new learning, providing examples of concepts, defining overarching ideas, and identifying any previous misconceptions. After the lesson, this tool can be used to assess or review skills that have been taught.

Figure 1: Vocabulary Foldables Showing Multiple Tabs

In our classroom of 20 students, including 10 culturally and linguistically diverse learners, 5 of whom were ELs, we had recently completed a math unit on decimals. Students reviewed the rules for adding, subtracting, multiplying, and dividing decimals, and discussed the rules for solving these types of mathematical equations using their own definitions or terms. The teacher encouraged the class to use their L1 or L2, pictorial representations, and provide examples of how to solve these problems. It was remarkable to see how the students transformed when the classroom teacher encouraged the use of the L1: students stopped slouching in their seats, they whispered excitedly to their friends, and they began to ask questions about how much of their L1 they could use and what to do if they didn't know how to write a word.

Together the class constructed the Vocabulary Foldable and the teacher provided the outside terms to write on the tabs. The teacher used a think aloud technique to demonstrate for the students how he might approach recording his background knowledge on the first tab. He then prompted students with frequent questioning and rephrasing to recall and record information as they completed the tabs on their Vocabulary Foldables. Students were encouraged to do this part individually, but they were allowed to ask their shoulder partner for clarification or ideas as needed. During this time, we witnessed two amazing things.

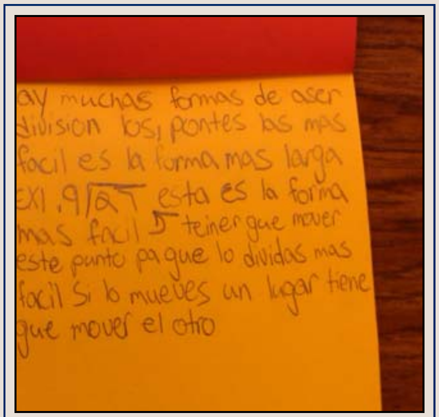

Figure 2. Component of Vocabulary Foldable Completed in Spanish.

First, we observed a pair of Hispanic students working together on their foldables utilizing their L1. One student had a higher level of understanding in his written native language and was scaffolding for his peer. He was explaining things in Spanish and clarifying terms for his shoulder partner. Both were excited to show us their work (Figure 2) and explain how certain words sounded the same in English and in Spanish, such as division/*división*. These students were making connections to mathematical cognates without having explicit instructional guidance. Second, we observed one student individually complete his foldable in Mandarin using the mathematical symbols from his L1 and L2. When asked if he could share his work with us, he proceeded to share information from the foldable in English. When asked why he chose to write in Mandarin instead of English, the student said it was because he felt more comfortable writing in Mandarin because that is what his parents used at home.

When a teacher and students work together to generate a joint product [3], a classroom environment is created in which the members of the classroom work together as a community of learners that embraces diverse perspectives. Joint productivity can increase interaction in the classroom, as students are motivated to assist their peers for a common outcome. The frequent discussions among students support the authentic application of academic language. We saw evidence of this kind of joint productive activity in the classroom we observed.

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Leveraging Spanish-Speaking ELs' Native Language to Access Science

Marco Bravo

Spanish and English share many cognates—words related by descent that are often more or less similar in form and meaning. Some words are highly frequent in Spanish (e.g., *castigar, edificio*) but less frequent in English (e.g., *castigate, edifice*). These cognate types represent a linguistic resource that Spanish-speaking ELs can tap into to make sense of academic science vocabulary. Given that science exposes students to a large corpus of academic terms, strategies to better understand them are critical. This article describes cognate strategies that can help Spanish-speaking ELs make sense of many science concepts.

Cognates & Science

An analysis of the frequency of key vocabulary in three science units revealed a substantial number of these frequency-imbalanced cognate pairs; that is, the Spanish member has a higher frequency than the English counterpart [1]. In this linguistic analysis a critical science word list was established, a cognate classification scheme was implemented, and a cognate frequency was conducted in English and Spanish. The science word list (*n*=86) was established from a set of words that science educators on our research team identified as essential for students to know in order to participate fully in the science activities of three units. With respect to the cognate classification scheme, words were classified as: (a) no shared cognate; (b) false cognate *(globe/globo)*; (c) low-frequency English word: low-frequency Spanish word *(organism/organismo)*; (d) high-frequency English word: low-frequency Spanish word *(question/cuestión);* (e) high-frequency English word: high-frequency Spanish word *(animal/animal)*; (f) low-frequency English word: high-frequency Spanish word *(solar/sol).*[1]

Findings from this study revealed that over three-fourths of words were Spanish/English cognates (76%). Within the entire corpus, 38% (or half of the words with cognates) were high-frequency words in Spanish (Table 1). By contrast, the percentage of cognate pairs with a high-frequency English word was considerably less (13% of the entire corpus). Additionally, less than 5% of words were false cognates, words that sound and look the same, but do not share a similar meaning (e.g., in Spanish *carpeta* means *folder*, not *carpet*), a common reason why cognates are rarely brought to the attention of foreign language learners. Yet, in science, this issue does not seem to be a pitfall.

Did You Know?

The USDE Office of International Education collected information in consultation with federal agencies about areas of national need and languages in which knowledge is critical in order for [the] U.S. ...to compete globally (http://www2.ed.gov/about/offices/list/ope/iegps/consultation.doc). The responses of these agencies are summarized in the chart below.

Federal Agency	Number of Languages Specified	Highest Priority Languages
Dept. of Agriculture	8	Chinese, Arabic, Farsi, Hindi, Urdu, Russian, Japanese, Korean
Dept. of Commerce	5	Arabic, Mandarin Chinese, Spanish, Portuguese, Japanese
Dept. of Defense	13	Arabic, Chinese, Dari, Farsi, Hausa, Hindi, Igbo, Pashto, Russian, Swahili, Somali, Urdu, Yoruba
Dept. of Health and Human Services	17	Arabic, Farsi, French, German, Hausa, Hindi, Korean, Portuguese, Russian, Spanish, Swahili, Tagalog, Thai
Dept. of Housing and Urban Development	6	Chinese, Japanese,Korean, Spanish, Russian, Vietnamese,
Dept. of Labor	6	Arabic, Chinese, Farsi, French, Spanish, Urdu,
Dept. of State	20	Arabic, Azerbaijani, Bengali, Cantonese, Chinese, Dari, Farsi, Hindi, Kazakh, Korean, Kyrgyz, Nepali, Pashto, Russian, Turkish, Urdu
Dept. of Transportation	0	No recommendations at this time
Dept. of Treasury	34	Arabic, Bulgarian, Cantonese, Chinese, Czech, Danish, Dari, Dutch, Finnish, French, German, Greek, Hindi, Italian, Maltese, Portuguese, Russian, Somali, Spanish, Swedish, Vietnamese

Source: Wang, S. C., Jackson, F. H., Mana, M., Liau, R., & Evans, B. (2010). Resource Guide to Developing Linguistic and Cultural Competency in the United States. College Park, MD: National Foreign Language Center at the University of Maryland. Available at: http://www.nflc.org/publications/.

Cognate Strategy

Students growing up with two languages do not automatically recognize the existence of cognates [2], nor do they use them to uncover the meaning of unfamiliar English words [3]. Therefore, it is critical that instructional attention be devoted to helping Spanish-speaking ELs develop cognate strategies with content-rich text. The following guidelines have been found useful:

- Select a text and identify a small set of cognates. If necessary, have a bilingual colleague help compile a list of these words. Select words that are most related to the main ideas in the text.
- Before reading, introduce cognates to students. Explain what cognates are and how they can help them understand English words.
- Write a cognate on the board and ask a student to read it aloud (e.g., the Spanish word, *inventar*). Ask students to think of an English word that looks and sounds like the cognate (e.g., *invent*). Ask ELs to use each word in a sentence (in both languages) to demonstrate its usage.
- Ask students to think about the meaning of related English words (e.g., *inventions, inventor*) and to provide examples.
- Practice identifying cognates in the text selected. Write a list of cognates from the text on the board. Ask an EL to read the words aloud. Have all students search through the text for the English counterpart. Discuss the words' shared meaning.
- Post a class list of cognates on the wall and include cognates from different languages spoken by the students in your class. Have students add to the list over time.
- Once students are familiar with the cognates strategy, address false cognates. Invite ELs to create sentences (in both languages) in which each of these false cognates is used in context.

Conclusion

English has many Latin-based words and an abundance of Spanish/English cognates, which represents a linguistic resource for Spanish-speaking ELs, if they are taught how to use it. The strategy described above is one approach to leveraging students' funds of knowledge [4] so they can access highly academic vocabulary and science content.

Table1. The Cognate Classification

High Freq. Spanish/ High Freq. English (10%)	
Comparar	Compare
Disolver	Dissolve
Plantas	Plants
Inventar	Invent
Explicar	Explain

High Freq. Spanish/ Low Freq. English (10%)	
Tierra	Terrarium
Carne	Carnivore
Luna	Lunar
Sol	Solar
Observar	Observe
Ácido	Acid
Árbol	Aboreal
Minimo	Minimum
Adaptar	Adapt
Líquido	Liquid
Investigar	Investigate
Primero	Primary
Noche	Nocturnal
Comunicar	Communicate
Force	Force
Igual	Equivalent
Durar	Duration

Low Freq. Spanish/ Low Freq. English (48%)	
Adaptación	Adaptation
Reproducciones	Reproduce
Predecir	Predict
Fibroso	Fibrous
Abrasivos	Abrasive
Descomponedors	Decomposers
Composición	Composition
Disuelva	Dissolve
Erosión	Erosion
Descomposición	Decomposition
Isópods	Isopods
Hábitat	Habitat
Interdependencia	Interdependence
Sobrevivencia	Survival
Nutrientes	Nutrients
Ecosistemas	Ecosystem
Predador	Predator
Prevenir	Prevent
Volcan	Volcano
Estructura	Structure
Sobrevivir	Survive
Función	Function
Evaluar	Evaluate
Procedimiento	Procedure
Método	Method
Inferir	Infer
Clima	Climate
Examinar	Examie
Contraste	Contrast
Hipótesis	Hypothesis

Low Freq. Spanish/ High Freq. English (7%)	
Océano	Ocean
Sustancia	Substance
Insectos	Insect
Diseño	Design

No Cognate (25%)	
Measure	Sowbug
Compost	Earth
Mold	Test
Decay	Prey
Root	Seaweed
Shelter	Predator
System	Pollution
Behavior	Shoreline
Environment	Powder
Earthworm	Data

False Cognate (3%)	
Cuestión	Question
Iman	Magnet
Recordar	Record

Notes

1. Frequency of words in written English was established by consulting [5]. High-frequency words were identified as those that occur at least 10 or more times per one-million-word corpus. The Spanish word frequencies were tabulated using the online *Corpus del Español* [6]. The corpus is based on 100 million words containing both spoken and written Spanish. Criteria for establishing the word frequencies were as follows: (a) high frequency: words that occurred in written form 10 or more times per million words, (b) low frequency: words have less than 10 occurrences in written form per one-million-word corpus.

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Teaching Science to ELs: Collaborative Support from ESOL and Secondary Subject Area Teachers

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Science teachers have the formidable task of teaching science content to mainstream students. It is more of a task when the student does not speak English as a first language. Ideally, all pre-service science teacher preparation programs would be structured and organized to include the understanding of critical issues that influence the success of ELs and would prepare teachers fully to teach science to EL students, but usually this is not the case [1; 2]. Furthermore, to implement appropriate ESOL instructional and assessment strategies for ELs successfully, science teachers have an immediate need for resources at their schools.

Two major resources that science teachers usually do not consider as they prepare to teach science to ELs are the trained ESOL professionals and the other subject area teachers. Besides having working relationships with fellow science colleagues, science teachers benefit from an ongoing structured exchange with the ESOL personnel represented by trained paraprofessionals, ESOL community liaisons, ESOL resource teachers, and possibly the Sheltered Language Arts/ESOL teacher that may be assigned to the school.

Collaborating with ESOL Personnel

It is common for science teachers to not approach ESOL personnel for assistance unless there is a problem such as discipline or language or there are cultural misunderstandings. Science teachers use teaching strategies they think will work for this population and hope for the best. They typically may give the ESOL professionals a list of vocabulary words to review for a test or a list of concepts that may need to be translated into their ELs' first language for "better understanding." ESOL personnel can offer so much more beyond these typically requested services. Collaborating with the ESOL personnel should begin when the science teacher is informed of having ELs in the science classroom. Developing working relationships that include regularly scheduled meeting times to discuss effective instructional and assessment strategies for science that relate to lingual, cultural, and academic science content issues is imperative. A few examples are provided below.

Language. Science teachers need to be aware of the levels of English that are comprehensible for the EL. The ESOL personnel should be able to provide language proficiency levels in the language domains of listening, speaking, reading, and writing for each student and provide the science teacher with terminology and cognates the EL may understand. They also should be familiar with possible grammatical and phonological transfer errors that may impede communication.

Culture. Science teachers should be aware of the range of culturally appropriate behaviors for ELs. These behaviors are also dependent upon cultural characteristics related to religion, gender, and social class. A science teacher may question why an EL will speak out of class freely but not answer questions when called on in class even when the teacher knows that the EL knows the answer. These behaviors can be explained to the science teacher by the ESOL personnel before they become a serious problem or misunderstanding.

Science Content. Extensive science terminology can be overwhelming for ELs to acquire in a short period of time since the student is learning the science content and another language at the same time [3].

Academic science language should be introduced in English and then only translated if needed for a comprehension check. ELs will not have the luxury of translating information from their native language to English during assessments [4]. ESOL personnel will be able to inform the science teacher what science terminology may be difficult and what concepts the student already knows. Many times immigrant ELs at the secondary level find U.S. science classes uninteresting since they have been introduced to these science concepts previously in their country.

Collaborating with Other Secondary Subject Area Teachers

Science teachers should encourage their non-science colleagues to incorporate grade-related science themes into their language arts, mathematics, and social studies curricula. Such integration is beneficial because it can reinforce what has been presented in the science classroom [5]. This is especially important at the secondary level where many times subjects are taught in isolation and by different teachers. Mainstream students especially find this reinforcement beneficial, but it is essential for the EL who needs repetitive exposure and a variety of applications for thorough understanding of concepts [6]. This interdisciplinary approach is commonly seen in the elementary grades as thematic units but tends to disappear at the secondary level.

Just as teaching of the English language should be acknowledged across all disciplines, science content also can be made visible throughout the curriculum [7]. For example, the science teacher can inform the other subject area teachers that "mountains" will be the subject content for the week, so, when opportunities arise, other teachers could 'recycle' the new vocabulary in their classes, selecting stories that may relate to mountains in language arts classes, devising problems that may relate to mountains in math classes, and discussing people who live in mountainous environments in social studies classes. These separate applications in different subject areas will reinforce new vocabulary and develop language skills. In the same manner science teachers should include other subject areas in their science classrooms. A scientific inquiry approach is important for all students, but especially ELs [8]. An example of an integrated science lesson across subject areas could be the following: the science teacher is required to teach the geological features of mountains.

After explaining mountain formations, the teacher then can assign a research project using technology. Students would be asked to find the names of the ten highest mountains in the world and give elevations in the English and metric systems (math). They would then determine temperature ranges, presence of animal or plant life, or oxygen levels according to altitude (science). Students would need to determine, graph, and then compare the longitude and latitude (geography, math, science) and then determine the groups of people who live in the area and the languages they speak (social studies). They could find stories (language arts) written about each of the mountains and how they influenced the people around them (social studies, environmental science). A lesson on mountains which might be potentially uninteresting can be "brought to life" by integrating other subject areas. This integrated approach also has the potential to activate the prior knowledge of the ELs who may have lived near these or other mountains and provide them the opportunity to contribute from personal experiences. Collaborating on a regular basis with ESOL personnel and other secondary subject area teachers brings richness to the task of teaching science and other content areas to ELs and supports their language development.

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